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THE POTATO BLIGHT IN INDIA

BY

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THE POTATO BLIGHT IN INDIA.

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JEHANGIR FARDUNJI DASTUR, B.Sc.,

First Assistant to the Imperial Mycologist.

THE "late blight" or "leaf curl" of potato is the most serious disease which attacks the potato. It is widely prevalent in Europe, America and Australia, but fortunately not in India except in the hills. The first outbreak of this disease in the plains was, according to Butler, reported in 1899-1900 from some villages in Bengal. After three or four years it disappeared and since then it was not known in any of the plains in India till 1912-13, when it worked havoc with the potato and tomato crops at Rangpur (Bengal), and destroyed the potato cultivation at Bhagalpur (Bihar).

The cause of the sudden appearance of the "late blight" on potato at Bhagalpur can however be explained. It so happened that the local store of seed potatoes was sold at an abnormally high price, and therefore the cultivators at the time of sowing got seeds from Darjeeling and Naini Tal. *Ph. infestans* (Mont.) de Bary, the cause of the "leaf blight" is present on these hills, and so the majority of the potato tubers, which were obtained from these places for seed purposes, were probably infected with this fungus. It has been shown by Melhus that the mycelium from infected tubers can under favourable circumstances work its way to the sprouts. Therefore, if the tubers obtained from Darjeeling and Naini Tal were already diseased, and if the conditions were favourable, the fungus from infected tubers would pass on to the shoots and there fructify, thereby infecting healthy plants. In the middle of December, 1912, there was some rain and after that nights were foggy and days cloudy; these were favourable conditions for

Phytophthora to spread. A fortnight later field after field was destroyed by *Ph. infestans*. As this disease was not known previously in Bhagalpur district, though potato has been cultivated there for several years, and as seeds were obtained from infected places at the time of sowing, it is very probable that the sudden outbreak for the first time in 1912 may have been due to the use of infected seeds.

The general appearance of the diseased fields was very characteristic. The leaves were almost completely destroyed in eight days by the disease and their rotting had set up a foul smell. The stems were green and stood erect as a rule. They showed many points of local infection and at these places they had turned brown and the epidermis and cortex showed longitudinal cracks. In severe cases of attack the stem gave way at the point of infection. The yield of tubers from diseased fields was abnormally low. The tubers were small in size but there was no supertuberation. When they were picked a large majority of them looked externally healthy, but after a few days' storage, characteristic brown or bluish brown sunken areas were visible; under these sunken areas the tissues had turned brown due to the presence of *Phytophthora* hyphæ. The extent of the browning of the tissues depends upon the time that has elapsed since the attack but more upon the surroundings. If the infected tubers are kept in a warm damp place, the fungus is in very favourable circumstances for overrunning the whole tuber. But if the surroundings be dry there is a check on the growth of the parasite, and the browning of the tissues may then remain only superficial. Whatever be the extent of the attack, the rot caused is always dry, but wet rot generally follows in the wake of *Phytophthora*, on account of putrefactive bacteria and saprophytic fungi getting hold of the diseased tissues.

It is of interest to note that the fields at the Sabour Agricultural College Farm that were sown in the end of November were practically free from the disease. Only a few plants had some of their leaves attacked by the blight; but fields in the near vicinity, sown in October, were totally destroyed. This suggests that if potato

tubers are obtained from infected places, it may be advantageous to sow them late, so that the plants mature in February or March, when the humidity is not so high as in December and January, and therefore even if *Phytophthora* be present, it is not able to make much progress.

Some potatoes picked from infected plants on the Sabour Agricultural College Farm were stored at Pusa. Some of them were kept covered with sand, others were kept uncovered on sand, and the remainder were buried underground. A few were also kept in a cold incubator at 75°F. The extreme moisture in the incubator caused the tubers to germinate immediately, and bacteria, *Rhizoctonia*, *Fusarium* and saprophytic fungi set up a wet rot and the whole lot of potatoes was soon destroyed. Only in one case was I able to trace definitely the presence of *Phytophthora* from among the mass of bacterial and fungal flora that had taken hold of the tuber. During the rains the tubers buried underground germinated prematurely and so naturally soon died, but the sprouts showed no signs of disease. What was left of the stored potato tubers covered and uncovered with sand, after rejecting from time to time those that had been attacked by *Rhizoctonia*, *Fusarium*, bacteria and insects, were planted in Pusa in October, 1913. They gave a perfectly healthy crop.

On the Sabour Agricultural College Farm tubers picked from diseased fields were used as seeds last year, and gave a crop free from *Phytophthora*, also in Bhagalpur district some cultivators used the same fields and the same affected potatoes from the 1913-14 crop without any bad effect. Again on Rangpur Farm one potato plot that was infected by *Ph. infestans* in 1912 grew a healthy crop of potatoes in 1913.

The above facts show that if potato tubers obtained from blighted fields are allowed to pass some part of a summer on the plains, these tubers will give a healthy crop and that the fungus is not able to survive the summer temperature even in the soil. The death of my pure cultures of *Ph. infestans* in summer also shows that this parasite cannot bear the heat of the plains. This renders

the appearance of "late blight" in 1912 at Bhagalpur more intelligible. In normal years small amounts of hill seed may be imported and probably experience sufficient heat on the plains to give a healthy crop. In 1912, however, the shortage of local seed perhaps necessitated the importation of hill seed relatively late in the season, in which case the imported seed might not have been subjected to sufficient heat to kill the fungus.

The remedial measures that suggest themselves from the study of this disease are the following :—

- (1) Potatoes to be used as seeds should be obtained, if possible, from places where this disease is not known.
- (2) If potato seeds are obtained from places not definitely known to be free from this disease, they should be got in time to allow them to pass a portion of the summer on the plains.
- (3) If potato seeds are got from infected or suspected localities after the summer has passed away, they should be sown late in November.

MICROSCOPIC CHARACTERS OF THE FUNGUS.

The general external morphology of the potato fungus is too well known to need repetition. But the internal morphology is of special interest as the observations of the various workers are discordant. De Bary, who has studied this parasite in such great detail and with such accuracy that the investigators who followed have not much to add, states that in the leaves the mycelium does not produce haustoria. In fact he considers *Ph. infestans* (Mont.) de Bary as the only species that has no haustoria, at least in the leaves. In tubers he has undoubtedly seen haustoria as has been pointed out by Mangin. De Bary says that in potato tubers, attacked by *Ph. infestans*, mycelial branches penetrate the host cell, but these branches hardly deserve a special name. Workers after de Bary, it seems, took for granted the absence of haustoria till Mangin, in 1895, proved their existence. Wehmer in 1897 saw

haustoria in potato tubers but he makes only a passing mention of them. In 1903 Delacroix confirmed Mangin's observations and in 1912, Jones, Giddings and Lutman followed suit. Appel and Kreitz studied this fungus in 1907 but they make no mention of either the presence or absence of haustoria and their drawing does not show them. In potato tubers I have found haustoria without any difficulty, even unstained free hand razor sections have clearly shown their presence in the affected cells (Figs. 1 to 7). Iodine or Bismark Brown or Congo Red shows them off more clearly. If the sections, without even any previous treatment with eau de Javel, are boiled with lactic acid and then warmed with cotton blue, washed and again boiled with lactic acid they show the presence of haustoria in the cells. The mycelium takes a blue colour but the tissues remain unstained. Haustoria in tubers are at first small and convex protuberances from the sides of the parent hypha; the cell wall forms a swelling at the point of attack which projects into the cavity of the host cell. As the haustorium grows it becomes either globoid, ovoid, finger-shaped or arched; it is either simple or branched.

With the growth of the haustorium, the sheath, which is round it and which appears to be a direct continuation of the cell wall of the host cell, keeps pace at least for some time, and gets more and more distended into the cell cavity. The formation of the sheath resembles rather that described by Grant Smith in *Erysiphe* than that described by Butler in *Pythium palmicorum*, but the persistence of a cellulose collar at the base of the haustorium, as in *Erysiphe*, has not been observed. This sheath either dissolves under the action of some toxic or enzymic substance that may be produced by the haustorium or not being able to grow further, as fast as the haustorium, gets ruptured (Figs. 5, 8 and 9). It is not essential for the haustorium to penetrate the enveloping sheath, for the former can, even when thus surrounded, draw upon the nutritive material contained in the host cell. Von Guttenberg has shown that the haustorium of *Ustilago Maydis* (D. C.) Corda, though surrounded by a cellulose sheath, still attracts the nucleus of the host cell towards it;

Leitgeb has shown that a parasitic fungus can attack the plasmatic contents of the host cell through its cell walls. Two or more haustoria have been frequently found surrounded by the same vesicle (Fig. 3). Mangin has shown the presence of the vesicle surrounding a haustorium in many *Peronosporaceæ* but he does not say if he has seen any in *Ph. infestans*, at least his figures do not show the vesicle. Delacroix, on the other hand, states that he has never seen it, and therefore thinks that the haustorium merely perforates the cell wall at the point of contact. Jones, Giddings and Lutman, who confirm Delacroix's statement as to the presence of haustoria, make no mention of the presence or absence of a vesicle round the haustorium. All the diseased cells do not necessarily possess haustoria. They are often completely absent; but whenever haustoria are present they are as a rule surrounded by a vesicle. When Delacroix is so emphatic as to the absence of the vesicle it does not seem probable that he has missed seeing it. It is therefore tempting to come tentatively to the conclusion that the presence or absence of the vesicle may have something to do with the different varieties of the cultivated potato. It would be interesting to examine several varieties affected with the blight to see how far this is true.

Mangin has found filiform haustoria in the affected cells in diseased leaves of the potato plant. Delacroix has also found similar haustoria. I have not examined fresh diseased leaves and free hand razor sections of old leaves and those preserved in spirit are not good enough to show the relation of the parasite to the host tissues. But if spirit preserved or dried leaves are first boiled with 3 per cent. caustic potash and after washing them with water if they are stained for about five minutes with a concentrated aquatic solution of rosazurin, the tissues when macerated on the slide show clearly the presence of filiform haustoria, quite different from those found in the tubers (Figs. 11-14). These haustoria in the leaves have also shown the presence of the vesicle surrounding them but not so often as those found in the tubers. Mangin records that different host plants of *Ph. infestans* (Mont.) de Bary, bear different sorts of haustoria, and, therefore, he says that it is not possible to

identify this fungus from the haustoria in absence of the fructification. Delacroix disagrees with him and points out that the haustoria in the diseased potato tubers are identical with those found in a diseased tomato fruit. I have had no opportunity to examine diseased tomato fruits, but haustoria in the stem of the tomato plant (Figs. 8-10) resemble those found in the potato tuber and those seen in the potato leaves agree in shape with those in the tomato leaf (Fig. 15) but the latter are longer.

The mycelium of *Ph. infestans* (Mont.) de Bary shows in the leaves, but not in the tubers, the ingrowths and plugs which Mangin considers to be characteristic of the *Peronosporaceae* and to be composed of callose. In a previous paper I have shown them, in *Ph. parasitica* Dast., to be composed of cellulose and not of callose. These ingrowths and plugs I have found in the potato fungus also to be of cellulose constitution. They are not dissolved by boiling with caustic potash and give cellulose reactions.

The cell walls between which the mycelium winds its way are affected by the fungus, at least in the tuber. They no longer give the characteristic cellulose reactions with Schulze's Solution, iodine and phosphoric acid and hæmatoxylin, such as are obtained in the normal tissues of the host.

From the literature which I have been able to consult it appears that Appel and Kreiz have observed changes in the starch grains of diseased cells of potato tubers. Appel and Kreiz's drawing shows that some of the starch grains of diseased cells have some of the eccentric markings of the grain highly prominent. I find that the fungus has some action, possibly some dissolving action, on starch grains. In a diseased cell, two kinds of starch grains are occasionally found. One kind contains the normal starch grain, globoid or ovoid in shape with a distinct hilum with fine eccentric markings and with smooth outline. The other kind consists of starch grains the shape of which is distorted (Fig. 16). They are less broad than the normal ones. The outline is corrugated, their hilum is not prominent and their eccentric markings have lost their fineness

and stand out boldly and are not so close to each other as in the normal starch grains. These deformed starch grains seem to be the result of the dissolving action of some enzymic substance that the fungus may be producing. These starch grains do not seem to be chemically changed for they respond normally to the ordinary chemical tests.

W. G. Smith's discovery of oospores of *Ph. infestans* in rotting stem and tubers of potato is at this moment merely of historical interest. When this discovery was announced, de Bary challenged the accuracy of the worker, and subsequent investigations have shown de Bary to be in the right. The oospores obtained by Clinton and Pethybridge in pure cultures have proved without doubt that W. G. Smith never saw the oospores of the potato fungus. Other investigators have followed W. G. Smith's method but they have failed to get his results. From January 1913 to June 1914, I have kept fresh diseased material under moist conditions and from time to time I have examined this material but have never found any of the resting spores found by W. G. Smith.

In February 1913, *Ph. infestans* was taken into pure culture. The conidia bearing mycelium was picked on a sterile needle and was used for inoculating French bean juice agar and Oat juice agar tubes. Aseptic slabs cut from the diseased portions of the tuber were also used in inoculating slants of the above agar media. On French bean juice agar the growth was very poor. Oat juice agar gave a fairly good growth, so also did sterilized potato slabs but still the fungus never seemed to thrive well in its saprophytic surroundings. I am inclined to believe that the quality of the media used was not the only factor which was responsible for the poor growth of the fungus, but that the temperature also had not a little to do with the growth. As the summer approached the growth became poorer and poorer and new subcultures showed very little activity of growth and the fungus ultimately succumbed to the heat of April and May. The fungus lived in culture for such a short time that no conclusion can be come to as to the relative value of different media. Sporangia were not observed in any cultures. No oospores were

produced, but in some of the cultures were found amber coloured, thick walled, globoid or pyriform swollen bodies, borne laterally or terminally on very broad stalks (Figs. 17-20). These swollen heads are cut off from the hypha by a septum and contain dense granular protoplasm with big irregularly formed oil globules. They were found in cultures growing in Oat juice agar and on the mycelium produced from the aseptically cut slabs used for inoculating agar tubes. Sometimes by the bifurcation of the stalk two such swollen bodies are produced together (Fig. 18). Clinton has found that the potato fungus in culture produces very frequently oogonia without antheridia. Judging from his photomicrographs, these oogonia very much resemble the swollen bodies I have found. But there are some very important differences. Clinton's oogonia have their wall thickened by the deposition on the outside of the original coat, and the protoplasmic contents of the oogonium contract to form the oosphere. In the swollen bodies under study I have never seen the formation of the oosphere nor the thickening on the outside of the original coat. The protoplasm has always been found to fill them completely. Their wall has always remained smooth and amber coloured. Pethybridge has also found oogonia without antheridia but these oogonia have produced parthenogenetic oospores. According to him a very characteristic feature of these oogonia is the reddish brown colouring matter in its walls. In this respect Clinton and Pethybridge are in agreement. The last author has also found these oogonia to be "distinctly brittle." This offers another point of difference, the swollen bodies found by me being not brittle. Pethybridge, like Clinton, has found the irregular thickening round the oogonium but this he thinks is an optical illusion due to the diffusion of colouring matter in the surrounding medium. According to Clinton the oogonia vary between 34 and 50 μ and according to Pethybridge they measure 31 to 40 μ . The swollen bodies found by me measure 24 to 38 μ . On account of these differences, I do not think these swollen bodies are either parthenogenetic oospores or oogonia without antheridia. I am inclined to consider them as resting conidia or chlamydospores resembling those found by

Butler and by Shaw in *Pythium palmivorum* Butl., by me in *Ph. parasitica* Dast., and in *Ph. Faberi* Maub., and by Butler and Kulkarni in *Ph. Colocasiæ* Rac. In general appearance these resting conidia and those of *Ph. infestans* look very much alike. In *Ph. parasitica* I have shown that the outer coat is of cellulose in constitution, and in this respect the resting conidia of the potato fungus agree with them for the outer coat of the former has also been found to give cellulose reactions. Pethybridge's figures 4 and 5 of Plate XLVI, and the photomicrographs of Clinton, Plate XXXVIII, Figs. B, F and H so much resemble my drawings that I have doubts if they are illustrations of immature oogonia without antheridia. There is no doubt that Pethybridge has seen parthenogenetic oospores, but in addition to these oospores, it is probable he has seen resting conidia which he mistakes for the former. Jones, Giddings and Lutman have also found these swollen bodies and they consider them to be "resting spores."

SUMMARY.

(1) The "late blight" or "leaf curl" of potato is not well known on the Indian plains, though it is present on the hills. This disease on the plains was first found in 1899-1900 in some villages of Bengal. In about three years it disappeared from these villages, but in 1912-13 potato and tomato crops at Rangpur and Bhagalpur were destroyed by this pest.

(2) The outbreak of "late blight" at Bhagalpur may be attributed to the use of infected seeds obtained, at the time of sowing, from Darjeeling and Naini Tal where this disease is of annual occurrence.

(3) At Bhagalpur, this disease was virulent enough to destroy healthy fields within a week. Its presence could be recognised from a distance by the foul smell emitted by the rotting of attacked leaves. The stems were found to be as a rule green and erect but denuded of almost all their foliage. They showed points of local infection and in severe cases they gave way at these points. The yield of tubers from diseased fields was very low; they were smaller in size but they showed no supertuberation.

(4) The majority of potatoes picked from diseased fields looked apparently healthy but when stored, the presence of the fungus was made evident by the appearance of depressed brown or bluish brown areas. The rot produced is always dry, the extent of the rot depending upon storage conditions.

(5) Experiments have shown that potatoes obtained from diseased fields at Bhagalpur gave healthy crops the next season even when sown on infected fields of the previous season. Potato seeds obtained from healthy localities were successfully grown on infected fields.

(6) These experiments and the death of pure cultures of the fungus in summer show that the heat of the plains is sufficient to kill the parasite. Therefore, potato seeds from infected localities should be obtained in time to allow the seeds to pass some part of the summer on the plains.

(7) The mycelium is intercellular and sends forth distinct haustoria in the affected cells. The haustoria are surrounded by a vesicle which is a direct continuation of the cell wall of the host cell. The cell walls between which the mycelium runs turn brown and do not give cellulose reactions. The fungus seems to have some dissolving action on starch grains contained in the host cells. These starch grains show distinct corrugation and are deformed in shape.

(8) In pure cultures, grown on artificial media, thick-walled, globoid or pyriform smooth walled bodies, borne laterally or terminally on broad stalks and amber in colour are produced. These are to be considered, in the author's opinion, as resting conidia similar to those found in *Pythium palmivorum* Butl., *Phytophthora parasitica* Dast., *Ph. Colocasiae* Rac. and *Ph. Faberi* Maub., and not parthenogenetic oospores.

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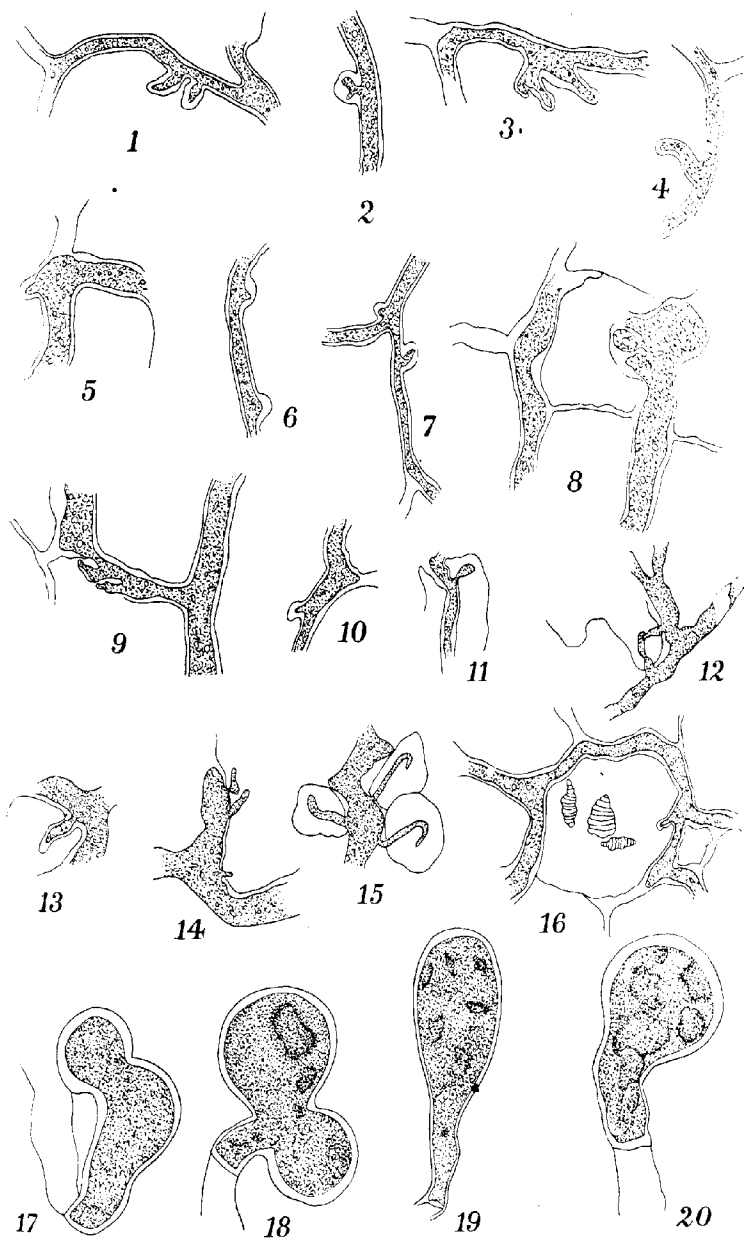
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EXPLANATION OF PLATE.

- Figs. 1—7. Haustoria of *Phytophthora infestans* from potato tubers. X 937.
The vesicles round the haustoria are clearly seen. In Fig. 5 the vesicle is partly dissolved.
Fig. 2 shows a branched haustorium. Fig. 3 shows the vesicle surrounding two haustoria one of which is branched.
- „ 8—10. Haustoria from the stem of a tomato plant. X 937.
Figs. 8 and 9 show the vesicle round the haustoria partly dissolved.
- „ 11—14. Haustoria from potato leaves. Figs. 11 and 12. X 750. Figs. 13 and 14. X 1160.
Fig. 12 also shows the cellulose plug in the hypha.
In Fig. 13 the vesicle round the haustorium is seen.
- Fig. 15. Haustoria from the leaf of a tomato plant. X 1160.
- „ 16. A diseased cell of a potato tuber containing deformed starch granules. X 750.
- Figs. 17—20. “Resting” conidia of *Ph. infestans* from pure cultures. X 960.
Fig. 18 shows a bifurcated “resting” conidium.



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